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Temporal activity of rural free-ranging dogs: implications for the predator and prey species in the Brazilian Atlantic Forest

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Abstract

Domestic or free-ranging dogs (*Canis lupus familiaris*) can have deleterious effects on wildlife, acting as predators or competitors to native species. These impacts can be highly important in fragmented pristine habitats or well-preserved areas located in human dominated landscapes and where biodiversity values are usually high, such as those in southeastern Brazil. Here we explored the level of overlap or mismatch in the distributions of activity patterns of rural free-ranging dogs and potential wild prey (*Didelphis aurita*, *Cuniculus paca*; *Sylvilagus brasiliensis*) and a wild predator (*Leopardus pardalis*) in areas of Atlantic Forest in southeastern Brazil. We further explored the possible influence of the wild predator on the dog presence pattern detected in the territory analyzed. Our camera-trap data (714 camera-trap days) showed that while rural free-ranging dogs display a cathemeral activity pattern, with activity peaks at dusk and dawn, ocelot and prey species are mainly nocturnal. Moreover, we found no evidence of an effect of ocelot presence, the distance to human houses and the presence of native forests on site occupancy by dogs. The ocelot activity

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patterns in this study were similar to those already reported in previous studies. On the other hand, previous studies have indicated that that free-ranging dogs are often reported to be more diurnal, and it seems that the rural free-ranging dogs in our study area may have adjusted their behaviour to be more active at dawn and dusk periods. This might be to both maintain some overlap with potential prey, e.g. *Sylvilagus brasiliensis*, and also to avoid ocelots by being less active in periods when this predator is more active (which also coincides with peaks in activity for potential prey species). We hypothesize that the presence of ocelots might be influencing the temporal niche dimension of rural free-ranging dogs. As a sustainable management strategy, we propose conserving territories to promote the presence of medium to large predators in natural areas, in order to control free-ranging dogs and protect their vertebrate prey species.

Keywords

Canis lupus familiaris, carnivores, competitive exclusion, *Leopardus pardalis*, mesopredators, prey, temporal segregation

Introduction

Dogs (*Canis lupus familiaris*) were the first mammals to be domesticated by humans (Morey 1994), and now occur on every continent (with the exception of Antarctica), with an estimated global population of more than 500 million (Vanak and Gompper 2009). Dogs owned by humans or associated with human houses but that use outdoor areas are not restricted to house limits (hereafter referred to as rural free-ranging dogs; Vanak and Gompper 2009). They occur on the outskirts of natural forested areas, as well as enter into those natural environments, where they may threaten wildlife due to predation (Galetti and Sazima 2006; Silva-Rodríguez et al. 2010; Doherty et al. 2017) and disease transmission (see Young et al. 2011; Doherty et al. 2017). Globally, domestic dogs have already contributed to the extinction of 11 vertebrate species and are listed as a potential threat to at least 188 threatened extant species (Doherty et al. 2017). Mammals, birds, reptiles, and amphibians all suffer negative impacts (Doherty et al. 2017). In tropical regions, studies have documented the impact of dogs on forest wildlife (Galetti and Sazima 2006; Lenth et al. 2008; Srbek-Araujo and Chiarello 2008; Lacerda et al. 2009; Paschoal et al. 2012; Carvalho et al. 2013; Lessa et al. 2016; Zapata-Ríos and Branch 2016) and have shown that dogs may have a negative effect on wild animals that move along trails and roads between forest fragments and in forest patches (Galetti and Sazima 2006; Lacerda et al. 2009; Silva-Rodríguez and Sieving 2012).

The negative impacts of domestic dogs can be a major problem for conservation units located near major urban centers, with the number and frequency of dog incursions increasing with proximity to urban areas (Lacerda et al. 2009; Paschoal et al. 2012; Carvalho et al. 2013; Lessa et al 2016). Dog-related predation in these areas often results in a decline of the relative abundance and occurrence of wild species (Galetti and Sazima 2006; Carvalho et al. 2013; Zapata-Ríos and Branch 2016; Farris et al. 2017). For example, Galetti and Sazima (2006) found 46 carcasses of 12 different wild species resulting from predation by domestic dogs in an Atlantic Forest reserve in Brazil. Moreover, during their 44-month study, they did not find any evidence of

selective predation, with dogs preying upon a wide range of vertebrates, from small amphibians to deer. Thus, the presence of dogs in protected areas, especially those that harbor endangered species, should motivate a proactive management plan focused on this domestic predator and aimed at reducing wildlife predation events (Lenth et al. 2008; Paschoal et al. 2012).

The impacts of competition for resources (e.g. prey) between dogs and wild carnivores are less well documented (Vanak and Gompper 2009; Paschoal et al. 2012; and Young et al. 2011 for a review), although some studies have shown that some wild species avoid areas frequented by dogs (Lacerda et al. 2009; Silva-Rodríguez and Sieving 2012). Prey may also avoid time periods where this predator is more active (Zapata-Ríos and Branch 2016), resulting in a temporal mismatch in activity between species. Dogs may themselves be preyed upon by larger carnivores, occasionally forming part of the diet of medium-sized to large felids, such as pumas (*Puma concolor* – Farrell et al. 2000), jaguars (*Panthera onca* – Whiteman et al. 2007; Foster et al. 2010), leopards (*Panthera pardus*) and lions (*Panthera leo* – Butler et al. 2004), or hyenids and canids, such as spotted hyaenas (*Crocuta crocuta* – Butler et al. 2004) and coyotes (*Canis latrans* – Grinder and Krausman, 1998). Large-bodied wild carnivores may kill dogs (Vos 2000; Butler et al. 2014), and thus, dogs may use different areas than larger carnivores, or the same area but avoid being active when a potential wild predator has an activity peak. For example, in southern Chile, most of the foraging excursions of the free-ranging dog take place during the day, while the activity of carnivores is mostly concentrated at night (Sepúlveda et al. 2015). Whatever the functional role played by free-ranging dogs in wild communities (e.g. as predator, competitor, or prey), their presence influences the activity of wild species and their use of the landscape (Lacerda et al. 2009; Silva-Rodríguez et al. 2010; Silva-Rodríguez and Sieving 2012); in turn, their spatial and temporal behavior when invading natural areas is influenced by potential predators, competitors or prey (Silva-Rodríguez and Sieving 2012). Understanding the dynamics of wild vertebrate communities inhabiting protected areas invaded by free-ranging dogs and the impact of this domestic predator is crucial for efficiently managing different forms of population control in order to reduce the impacts of free-ranging dogs. Nevertheless, in many tropical regions this important information is lacking. For example, the activity patterns of dogs and sympatric wild predators, competitors and prey is almost unknown in Brazil (Silva et al. 2018), and the influence of potential predators or competitors on the occupancy patterns of dogs, and vice versa, is still insufficiently studied in the country (but see Massara et al. 2018). Occupancy, which is the proportion of sites occupied by a species or population, is often used as a surrogate for the species habitat relationship (Guillera-Arroita et al. 2010). This metric can be influenced by imperfect detection, which can determine that an occupied site be classified as unoccupied. Thus, occupancy modeling approaches currently account for this bias and estimate simultaneously occupancy and detectability, leading to a more realistic perception of spatial use patterns (MacKenzie et al. 2006).

In this study, we used camera-trapping data from an Atlantic Forest area to: (1) compare the activity patterns of *Canis lupus familiaris* (rural free-ranging dogs) and *Leopardus pardalis* (ocelot); (2) examine the pattern of overlap of both carnivores with

three potential prey species (the big-eared opossum (*Didelphis aurita*), the spotted paca (*Cuniculus paca*) and the tapiti (*Sylvilagus brasiliensis*)); and (3) assess factors influencing the occupancy patterns of rural free-ranging dogs. We hypothesized that the activity and occupancy patterns of the dogs would be affected by the presence of ocelots (which are mainly nocturnal predators; Maffei et al. 2005; Di Bitetti et al. 2006; Massara et al. 2016). Specifically, we expected that, in areas with the presence of ocelots, rural free-ranging dogs would be mainly diurnal (e.g. Boitani and Ciucci 1995; George and Crooks 2006; Srbek-Araujo and Chiarello 2008; Silva et al. 2018), despite the nocturnal activity patterns of their potential prey, as a strategy to avoid the risk of being predated themselves by the ocelots. In addition, the ocelot activity patterns would follow those commonly described (i.e. mostly nocturnal), indicating that dogs have no effect on ocelot activity patterns.

Material and methods

Study area

The study was carried out in the Serra do Japi Biological Reserve (hereafter REBIO Serra do Japi) and its surrounding areas, located in the municipality of Jundiaí, state of São Paulo, southeastern Brazil (23°12' – 23°21'S and 46°30' – 47°05'W) (Fig. 1). REBIO Serra do Japi is located in the Atlantic Plateau, comprises an area of 2,071 ha, and has a strongly seasonal climate with hot-rainy (October to March) and dry-cold (April to September) seasons. Sampling plots were located in altitudes exceeding 1,040 m, covered by altitudinal mesophilic semideciduous forests (Carvalho et al. 2013).

Data collection

Surveys were conducted from July 2006 to February 2007 and July 2009 to February 2010, using seven and 10 camera traps in each period, respectively. The camera traps were located in different sites during each sampling period, but always placed on trails that were already established in the REBIO Serra do Japi (Fig. 1). Camera traps (Trapa Camera), using a 35 mm analog camera (Canon® model BF35), were activated by movement through a passive infrared beam. Sampling sites were approximately 1 km away from each other in each sampling period. Camera traps were set up on a tree trunk 30–40 cm above ground-level, directed across the trail (Srbek-Araujo and Chiarello 2005) and programmed to operate 24 h/day with a minimum inter-photo interval of 60 s (the maximum time period allowed by the device configuration). During 1 month in each of the dry and rainy seasons, each camera trap remained active in the field for 6 days of each week. The traps were removed on Saturdays to avoid camera damage or theft (e.g., by hikers at weekends). Films and batteries were changed during this time, and the cameras were reactivated on Sunday afternoon.

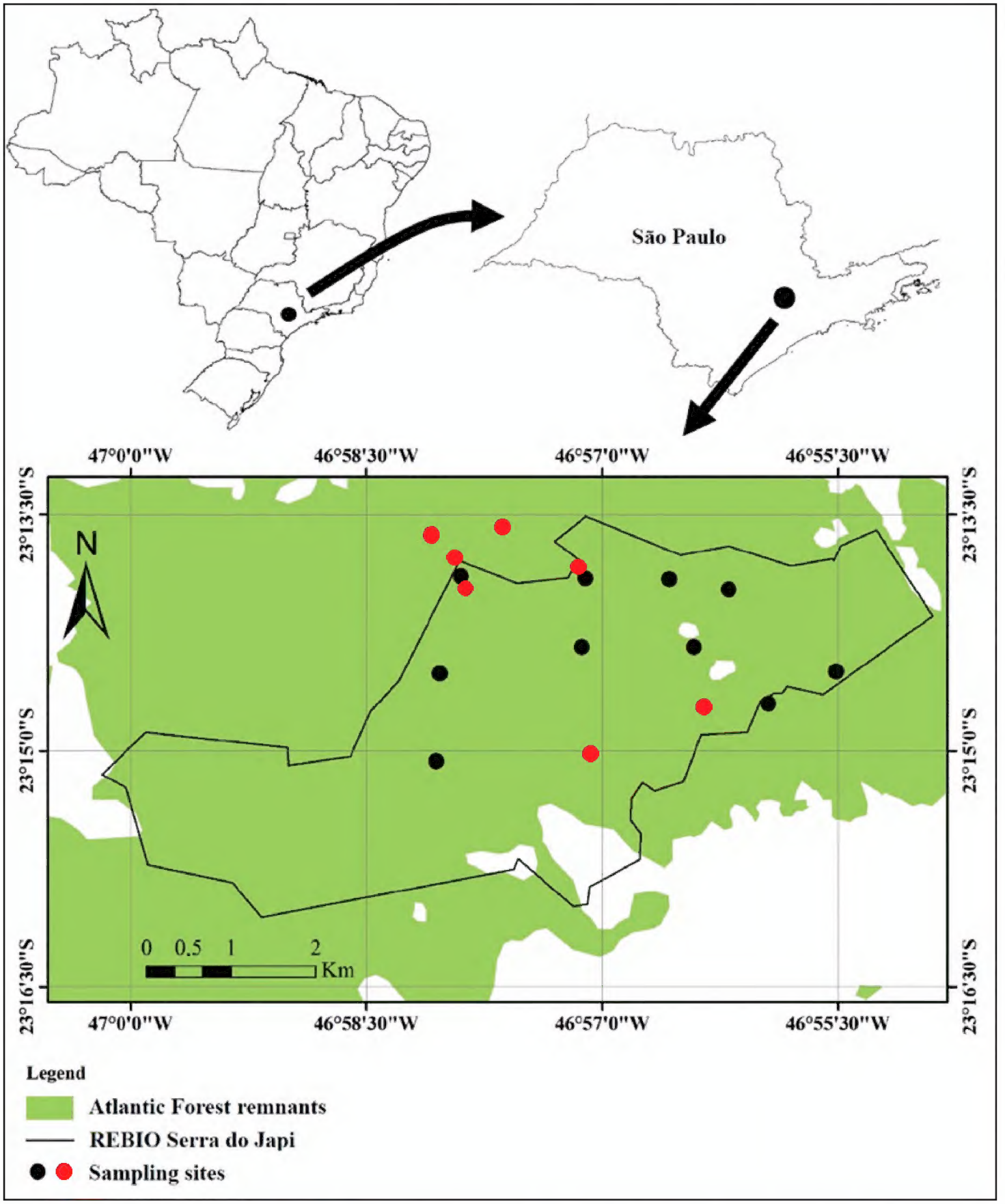

Figure 1. Study area location in São Paulo state, Brazil, and Atlantic Forest remnants in the REBIO Serra do Japi. The circles represent the sampling sites used to place camera traps. Red circles represent the surveys conducted from July 2006 to February 2007 and black circles represent the survey conducted from July 2009 to February 2010.

Data analysis

Sampling effort was defined as the number of camera-traps × number of sampling days (1d = 24h; Srbek-Araujo and Chiarello 2005). In relation to temporal activity, to ensure temporal independence of each detection event, for each camera we con-

sidered only the first record of the same species within a 1-hour interval (see Tobler et al. 2008). For the occupancy analysis, we considered only the first record of the same species within a 24-hour period (but as data was transformed to detection/non-detection within each 5-day period, this did not have any influence on the occupancy patterns described). We tested for activity clusters over a specific daily period (24h) for each species using Rayleigh's test and compared the activity patterns between species using Watson-Wheeler's test (Zar 1996). Rayleigh's test provides statistical significance for the average angle of a unimodal distribution, verifying the existence of a uniform circular distribution in a dataset (e.g. circadian activity). Watson-Wheeler's test verifies differences between two datasets that are circular in scale (Zar 1996). We used the data from the two datasets together because there were few records in each sampling period. In addition, when the activity was analyzed separately, considering the period between 2009 and 2010, this did not appear to be discrepant compared to both datasets between free-ranging dogs and the ocelot, and between the free-ranging dogs and the tapiti (see Suppl. material 1). We also used the approach suggested by Linkie and Ridout (2011) to evaluate the relationships between the activity rhythms of the predators (ocelot and rural free-ranging dogs) and prey species (tapiti, spotted paca, and big-eared opossum). We first converted the national time (linked to the Brasilia Standard Time, 3 h behind Greenwich Mean Time) to the solar time in order to correct for discrepancies associated with the daily period perceived by wildlife in the field and that registered in the collected data. We then used the independent detection records, which were considered as a random sample of the continuous temporal distribution of activity, to build a probability density function (Ridout and Linkie 2009) describing the species activity pattern, based on a non-parametrical kernel density (Ridout and Linkie 2009). This analysis was only implemented for cases with more than 10 detections. We also estimated the coefficient of overlap $\Delta 1$, which is most adequate when dealing with small sample sizes (Ridout and Linkie 2009; Linkie and Ridout 2011). $\Delta 1$ ranges from 1 (full overlap) to 0 (no overlap). We adopted the threshold mentioned by Monterroso et al. (2014) to qualitatively classify the degree of overlaps between species (i.e. $\Delta 1 \leq 0.66$, low overlap; $0.66 < \Delta 1 < 0.76$, moderate overlap; $\Delta 1 \geq 0.76$, high overlap; Curveira-Santos et al. 2017). Analyses were performed in Oriana (Kovach 2004) and R software v. 3.3.2 (R Core Team 2011), in which we used the R package "overlap". We did not consider moonlight effect, because camera traps where set under a dense tropical forest canopy which prevented/minimized moonlight penetration.

Due to the asymmetry in activity patterns of dogs and ocelots (see results), we also tested for the influence of ocelot presence, type of habitat (Habitat; Atlantic Forest vs *Eucalyptus* plantations), distance to patch edge (Dist_edge) and distance to human houses (Dist_houses) on the occupancy by dogs (Ψ). In these models, we accounted for variations in detectability (p) by building single-season occupancy models (MacKenzie et al. 2006). Different areas were sampled in each year-period (seven cameras active in 2006–2007 and 10 in 2009–2010, located in different areas). Thus, due to the limited sampling period in each year-period (i.e. 2006–2007 and 2009-2010), we assumed the populations to be closed in each sampling period and region, with reduced probability of immigration and emigration events. Due to the limited number

of stations, we assumed that we were assessing the probability of use rather than the probability of occupancy. We pooled the detections of dogs over five consecutive days to generate a presence (dog detection in a five days period)/absence (no detection) matrix. Usually, 5–10 days occasion lengths are recommended for rainforest mammals (Ancrenaz et al. 2012), which will prevent having extremely low detection probabilities that reduce the accuracy and applicability of occupancy models (Ancrenaz et al. 2012).

The habitat type of each camera-trap, the distance between each trapping site and human houses and patch edge were tested as covariates influencing occupancy and detectability. We first tested for spatial autocorrelation in the detection frequency of rural free-ranging dogs in all cameras using Moran's I Index (Legendre 1993) as implemented in the package "ape" (Paradis et al. 2004) in R v. 3.3.2 (R Core Team 2011). We also assessed the correlation between continuous variables (i.e. distance covariates) using the Spearman correlation rank (r), and in cases of collinearity, we retained the variable most highly correlated with the dependent variable (dog detection). In the modeling procedure, we adopted the strategy suggested by Doherty et al. (2012) that consisted in building models representing all possible combinations of covariates considered as influential for occupancy (Ψ) and detectability (p). To assess the possible influence of ocelots on occupancy patterns of free-ranging dogs, we also tested the presence of ocelots as a covariate. However, to avoid a bias arising from false negatives of ocelot occupancy, we used the conditional occupancy probability of ocelots (Ψconditional_Ocel) estimated for every camera, as a candidate co-variate in the dog occupancy models (Massara et al. 2016). The conditional occupancy probability was estimated using a single-season occupancy approach (MacKenzie et al. 2002; 2006), considering all combinations of covariates. The same procedure was implemented in modelling ocelot occupancy patterns, but using the conditional occupancy probability of rural free-ranging dogs.

Model selection was performed using the Akaike Information Criterion adjusted for small samples (AICc; but see below the use of QAICc after overdispersion was assessed) to rank models according to the model's Akaike weights and the change in AICc score – ΔAICc (Burnham and Anderson 2002). Based on the models' Akaike weights, we used model averaging to determine variables' coefficients (as suggested by Doherty et al. 2012). Model fit was evaluated using the Pearson chi-square statistic and the model's dispersion assessed by the overdispersion parameter c-hat (č) (MacKenzie and Bailey 2004). Values of č greater than 1 indicate a wider variation in the observed data than expected by the model, and lower than 1 the inverse (MacKenzie et al. 2006). Although the Pearson chi-square statistic was not significant (see Results), the č estimated value was greater than 1 for the free-ranging dog models, indicating some level of overestimation. In such cases, MacKenzie and Bailey (2004) suggested the use of QAICc (quasi-likelihood version of AICc) in model selection and averaging. Thus, we applied a QAICc approach to estimate the models and weights of the covariates included in the free-ranging dog occupancy models. Occupancy modeling was performed using the "unmarked" package (Fiske and Chandler 2011), and model selection was performed using the "AICcmodavg" (Mazerolle 2017) and "MuMin" (Bartón 2014) packages. All packages were uploaded in program R v. 3.3.2 (R Core Team 2011).

Results

Overlap in temporal activity between species

From a total of 714 camera-trap days (17 cameras-trap running for 42 days), we revealed a nocturnal activity pattern for *D. aurita*, *C. paca*, *S. brasiliensis*, and *L. pardalis*, whereas the domestic dog presented a cathemeral pattern (Table 1; Fig. 2). No differences were detected between the activity patterns of *L. pardalis* and its wild prey, with an overlap always greater than 65% (Table 1; Fig. 2). Δ1 values were all above the threshold of 0.66 (low overlap), confirming this pattern. Ocelots had an intermediate overlap of diel activity patterns with big-eared opossums (Δ1 = 0.69) and a high overlap with tapitis (Δ1 = 0.80) and spotted pacas (Δ1 = 0.83) (Table 1; Fig. 2).

Domestic dogs showed a cathemeral pattern, with peak activity at dusk and dawn (Fig. 2). The overlap between this canid and its potential prey was low, reaching a maximum of 44% with the spotted paca (Table 1; Fig. 2). Again, this pattern was confirmed by Δ1 values that indicate a low overlap of activity patterns (i.e. Δ1 ≤ 0.66). The overlap was lower for the spotted paca (Δ1 = 0.24), followed by the big-eared opossum (Δ1 = 0.34) and the tapiti (Δ1 = 0.48) (Table 1; Fig. 2). Both rural free-ranging dogs and ocelots increased their activity at dusk, with a marked decrease in dog activity during the night, as that of ocelots increased. At dawn, dogs again became more active as ocelots greatly decreased their activity (Fig. 2). The coefficient of overlap Δ1 reached intermediate values (Δ1 = 0.69), although very close to the considered threshold (0.66) associated with a low overlap.

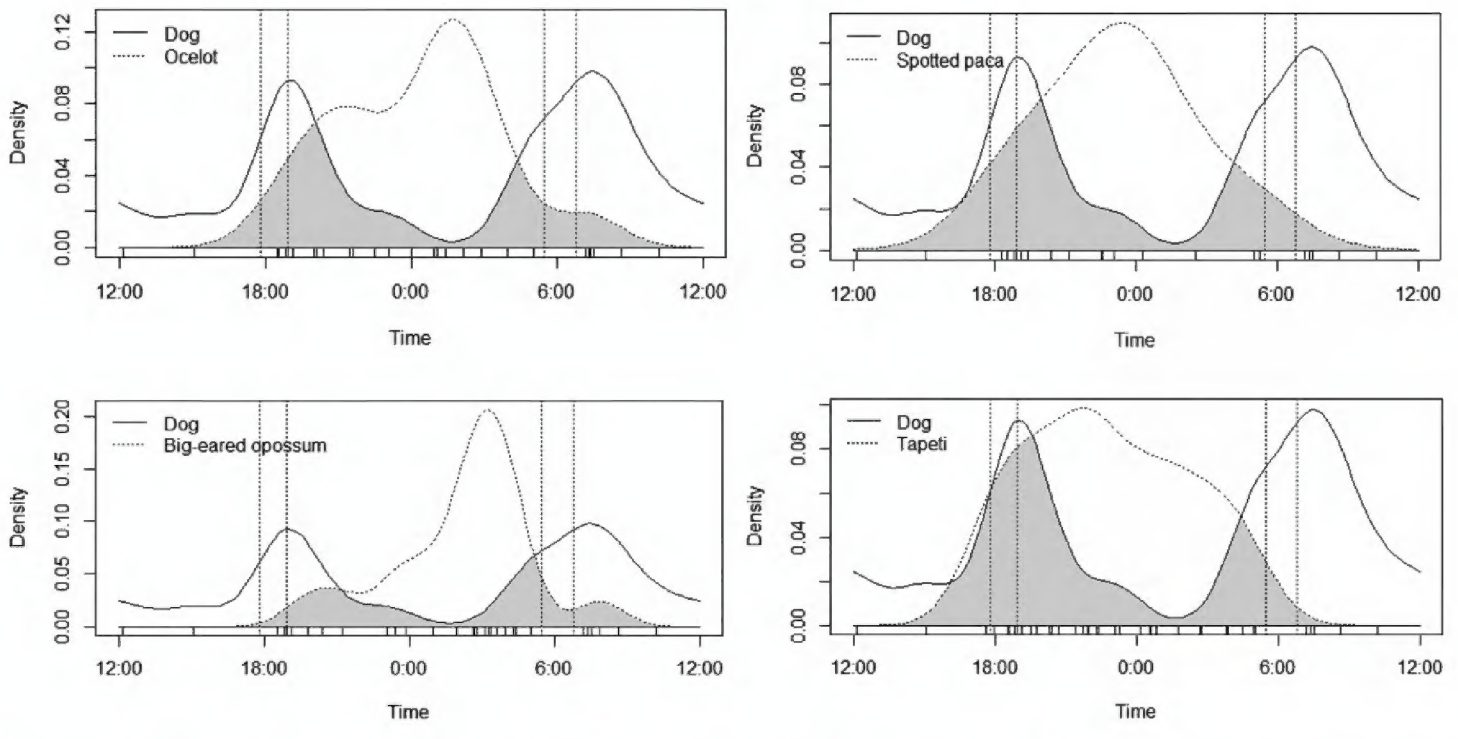

Figure 2. Kernel densities for paired activity patterns of free-ranging dogs and ocelot, spotted paca, big-eared opossum and tapiti in REBIO Serra do Japi. Individual records are shown as short vertical lines above the x-axis. The grey areas represent overlapping activity periods and the vertical dashed lines the approximate time of sunrise and sunset.

Table 1. Number of detections, relative frequency (RF), type of activity and main activity period (Mean Vector in time and angle) of the studied taxa in the REBIO Serra do Japi, Jundiaí, São Paulo: Daur – *Didelphis aurita* (big-eared opossum); Cfam – *Canis lupus familiaris* (free-ranging dogs); Lpar – *Leopardus pardalis* (ocelot); Cpac – *Cuniculus paca* (spotted paca); Sbra – *Sylvilagus brasiliensis* (tapiti). Statistical significance (*p*) of Rayleigh's test for comparing the unimodal distribution of activity patterns and Watson-Wheeler's test for assessing differences in activity between species, as well as the coefficient of overlap between activity patterns (Δ1), are also presented.

Taxa	Number of detections (RF, %)	Rayleigh test (*p*)	Main activity period	Mean Vector in time and angle (μ)	Watson-Wheeler test (*p*) and overlap (%)		Coefficient of overlap Δ1	
					Lpar	*Cfam*	*Lpar*	*Cfam*
Daur	17 (18.28)	<0.001	Nocturnal	02:21 (35.41°)	0.111 (65)	<0.001 (37)	0.69	0.34
Cfam	19 (20.45)	>0.05	Cathemeral	08:47 (131.76°)	<0.001 (43)	–	0.44	–
Lpar	16 (17.20)	<0.001	Nocturnal	00:14 (3.703°)	–	<0.001 (43)	–	0.44
Cpac	11 (11.82)	0.003	Nocturnal	23:12 (348.01°)	0.602 (70)	0.009 (44)	0.83	0.24
Sbra	30 (32.25)	<0.001	Nocturnal	22:41 (340.33°)	0.529 (73)	<0.001 (37)	0.80	0.48
Total	93 (100)	–	–	–	–	–	–	–

Rural free-ranging dog occupancy patterns

We did not detect any significant spatial autocorrelation in detection frequency of rural free-ranging dogs (I = -0.059; $p = 0.957$). Distance to human houses (Dist_houses) and to patch edges (Dist_edge) were highly correlated ($r = 0.912$, $p < 0.001$). We, therefore, excluded the distance to edges, as it was the variable less associated with the dependent variable ($rr_{Dist_edg\text{-}dog} = 0.181$ $r_{Dist_houses\text{-}dog} = 0.275$). The null occupancy and detection estimates for rural free-ranging dogs were 0.472 (SE = 0.145) and 0.291 (SE = 0.082), respectively.

The full model produced for the rural free-ranging dogs, i.e. considering all the variables influencing detectability and occupancy, showed a good model fit ($\chi^2 = 70.603$, $p = 0.200$), but indicated wider variation in the observed data than expected, i.e. overdispersion (č = 1.29). Thus, model ranking, averaging and estimation of variable coefficients were based on QAICc (see Methods). The total set of 53 models produced (see Suppl. material 2) were ranked according to QAICc values. The most supported model, as evidenced by the lowest QAICc value and highest QAICc weight, was the null model (Table 2). This indicates that the selected covariates were not accounting for much of the variation in the data. However, the analysis of the covariates' cumulative weights shows that the habitat type was the most influential variable for probability of detection and occupancy (Table 3; Suppl. material 3), with the influence of ocelot probability of presence being negligible on both parameters.

Ocelot occupancy patterns

We did not detect any significant spatial autocorrelation in detection frequency of ocelots ($I = -0.070$; $p = 0.920$). Due to correlation problems (see above), we excluded the distance to edges from the analysis. Null occupancy and detection estimates for ocelots were 0.765 (SE = 0.019) and 0.147 (SE = 0.037), respectively.

Table 2. Top ten ranked models for occupancy of rural free-ranging dogs in the Serra do Japi Biological Reserve, Brazil (*N* – Number of parameter in the model; QAICc – quasi-likelihood version of the Akaike Information Criterion, adjusted for small samples (i.e. accounting overdispersion); ΔQAICc – Difference between the lowest QAICc and the model's QAICc; QAICcWeight – quasi-likelihood version of the Akaike weight; Cumulative QAICcWeight – Cumulative weight of the models; psi – occupancy; p – detectability; Habitat – Type of habitat; Dist_houses – distance to Human houses; Ocelot – Conditional occupancy of ocelot in each camera-trap).

Occupancy model	*N*	QAICc	ΔQAICc	QAICcWeight	Cumulative QAICcWeight
psi(.)p(.)	2	65.951	0.000	0.484	0.484
psi(.)p(Habitat)	3	68.583	2.632	0.130	0.614
psi(.)p(Ocelot)	3	69.184	3.233	0.096	0.710
psi(.)p(Dist_houses)	3	69.202	3.251	0.095	0.805
psi(Ocelot)p(Dist_houses)	4	72.321	6.369	0.020	0.825
psi(Dist_houses)p(Habitat)	4	72.388	6.437	0.019	0.844
psi(Habitat)p(Dist_houses)	4	72.448	6.497	0.019	0.863
psi(Habitat)p(Ocelot)	4	72.475	6.524	0.019	0.882
psi(Ocelot)p(Habitat)	4	72.513	6.562	0.018	0.900
psi(Dist_houses)p(Dist_houses)	4	72.665	6.714	0.017	0.917

Table 3. Cumulative QAICc weights of the explanatory variables for models of occupancy (Ψ) and detection (p) of free-ranging dogs in Serra do Japi Biological Reserve, Brazil. QAICc – quasi-likelihood version of the Akaike Information Criterion, adjusted for small samples (i.e. accounting overdispersion); Ψ – occupancy; *p* – detectability; Habitat – Type of habitat; Dist_houses - distance to Human houses; Ocelot – Conditional occupancy of ocelot in each camera-trap; b - Covariates coefficient; SE – Standard error of the covariates coefficient; z-value - Wald statistic for testing the hypothesis that the coefficient is zero; p-value – statistical significance.

	Covariate	b	SE	z-value	*p*-value	Cumulative QAICc weights
Detection (p)	Habitat	1.676	19.999	0.084	0.933	0.204
	Dist_houses	-0.088	0.274	0.322	0.748	0.172
	Ocelot	-0.061	0.239	0.255	0.799	0.163
Occupancy (Ψ)	Habitat	0.914	13.904	0.066	0.948	0,077
	Ocelot	-0.412	3.877	0.106	0.915	0,068
	Dist_ houses	0.052	0.272	0.191	0.849	0,067

The full model produced for the ocelots showed a good model fit (χ^2 = 34.941, *p* = 0.300), with negligible overdispersion (č = 0.95), and therefore we used the AICc for model ranking, averaging and estimation of variables coefficients. From the set of 53 models produced, seven (including the null model) had a ΔAICc < 2 (Table 4), and as such could be considered to be part of the set of best models for describing ocelot occupancy patterns (Burnham and Anderson 2002). However, most of the variables had large coefficients and standard errors, (Table 5), indicating that the models were not very robust.

Table 4. Top ten ranked models for occupancy of ocelots in the Serra do Japi Biological Reserve, Brazil (N – Number of parameter in the model; AICc –Akaike Information Criterion, adjusted for small samples; ΔAICc – Difference between the lowest AICc and the model's AICc; AICcWeight – Akaike weight; Cumulative AICcWeight – Cumulative weight of the models; psi – occupancy; p – detectability; Habitat – Type of habitat; Dist_houses - distance to Human houses; Dog – Conditional occupancy of dog in each camera-trap).

Occupancy model	N	AICc	ΔAICc	AICcWeight	Cumulative AICcWeight
psi(Dist_houses+Dog)p(Dist_houses+ Dog)	6	87.87	0.00	0.130	0.13
psi(Dist_houses+Dog)p(Dist_houses +Habitat)	6	88.12	0.25	0.115	0.25
psi(Dist_houses+Dog)p(Dist_houses)	5	88.51	0.64	0.095	0.34
psi(Dist_houses+Dog)p(Habitat)	5	88.77	0.89	0.083	0.42
psi(.)p(.)	2	89.19	1.31	0.068	0.49
psi(Dist_houses+Dog)p(Dist_houses +Habitat+Dog)	7	89.68	1.81	0.053	0.54
psi(.)p(Habitat)	3	89.78	1.91	0.050	0.59
psi(Dist_houses+Dog)p(Dog)	5	89.95	2.08	0.046	0.64
psi(Dist_houses+Dog)p(Habitat+Dog)	6	90.48	2.61	0.035	0.68
psi(Dist_houses+Habitat+Dog)p(Dog)	6	90.86	2.99	0.029	0.70

Table 5. Cumulative AICc weights of the explanatory variables for models of occupancy (Ψ) and detection (p) of ocelot in the Serra do Japi Biological Reserve, Brazil. AICc –Akaike Information Criterion, adjusted for small samples; Ψ – occupancy; p – detectability; Habitat – Type of habitat; Dist_houses - distance to Human houses; Dog – Conditional occupancy of dog in each camera-trap; b - Covariates coefficient; SE – Standard error of the covariates coefficient; z-value - Wald statistic for testing the hypothesis that the coefficient is zero; p-value – statistical significance.

	Covariate	b	SE	z-value	p-value	Cumulative AICc weights
Detection (p)	Habitat	-0.383	0.756	0.506	0.613	0.486
	Dist_houses	0.059	0.201	0.295	0.768	0.521
	Dog	-0.022	0.181	0.120	0.905	0.423
Occupancy (Ψ)	Dist_houses	-8.121	38.734	0.210	0.934	0.679
	Dog	11.951	54.127	0.221	0.853	0.674

Discussion

Temporal activity patterns

In common with our results for the REBIO Serra do Japi, *D. aurita*, *C. paca*, *S. brasiliensis*, and *L. pardalis* have previously been described as having nocturnal habits in South American tropical forests (Alves and Adriolo 2005; Di Bitetti et al. 2006; Michalski and Norris 2011; Blake et al. 2012; Ferreira and Vieira 2014; Massara et al. 2016; Pratas-Santiago et al. 2016; Silva et al. 2018). We found no differences between activity patterns of ocelot and their prey, and they showed high overlap in temporal activity. Similarly, previous studies have shown a substantial overlap between ocelot activity and the foraging period of their potential prey (Emmons et al. 1989; Porfirio et al.

2016; Pratas-Santiago et al. 2016). Moreover, despite the tendency for prey to reduce their activity in periods when predators are more active (Eccard et al. 2008; Gliwicz and Dabrowski 2008), in South America, there seems to be a strong overlap between prey and predator activity patterns (e.g. Blake et al. 2012; Silva-Rodríguez and Sieving 2012; Foster et al. 2013; Pratas-Santiago et al. 2016), suggesting that predators are more efficient in adjusting their activity to reduce energy costs (Foster et al. 2013), than are prey in avoiding the high activity periods of predators.

Here, the free-ranging dogs showed cathemeral activity pattern with peaks at dusk and dawn. This pattern is different to that described by other studies performed within and around protected areas in the Atlantic Forest, in which domestic dogs were mostly reported to be active during the day (Alves and Andriolo 2005; Srbek-Araujo and Chiarello 2008; Silva et al. 2018). Although rural free-ranging dogs present a peak of activity at dusk and dawn, these canids have low overlap with their potential wild prey. As these prey species show similar activity patterns to those already described in other Neotropical areas (see above), the presence of dogs within the REBIO seems to have little or no effect on the activity patterns of these vertebrates.

As ocelots in our study area maintain the activity patterns recorded in preserved environments (e.g. Maffei et al. 2005; Di Bitetti et al. 2006; Massara et al. 2016; Pratas-Santiago et al. 2016), it seems that the presence of rural free-ranging dogs is not having a large effect on their temporal behavior. Other studies have detected a negative influence of the number of dogs within Brazilian Protected Areas on ocelot abundance (Massara et al. 2015). However, we do not consider abundance in our spatial analysis, but only presence-absence data. Inversely, no nocturnal activity was detected for rural free-ranging dogs as mentioned in other regions that present potential nocturnal predators such as coyotes (*C. latrans* - e.g., George and Crooks 2006). In the temperate rainforest of southern Chile, foraging excursions of free-ranging dogs occur mostly during the day (Sepúlveda et al. 2015). There, it is expected that most wild carnivores inhabiting the area (including the puma; e.g., Adania et al. 2017) concentrate their activity at night. These patterns and the fact that the dogs detected in our study area were usually smaller (when compared to ocelots that can reach 18 kg; Paschoal et al. 2012) and often travelled alone (see Figure S1 in the Suppl. material 4), leads us to suspect that the dogs may be avoiding ocelots due to either interference or predation. However, further studies are needed to confirm this trend. Furthermore, the presence of top predators such as pumas (which were detected in our camera-trap set but in low abundance; Carvalho et al. 2013) may directly constrain rural free-ranging dog activity (through predatory pressure). In addition, during fieldwork, we found two carcasses of domestic dogs, one a fresh kill, with signs of predation and partially consumed. Next to the fresh dog carcass, we also found ocelot footprints and no other footprints from any other large predator (e.g. *P. concolor*). Therefore, we consider there was a probability that this kill was carried out by an ocelot. The carcasses were of rural free-ranging dogs of similar size to the individuals recorded on the cameras in the REBIO Serra do Japi (12–15 kg; see Figure S1 in the Suppl. material 4). There are records of ocelots preying upon and consuming wild prey that can reach up to approximately 40 kg (e.g. pampas deer, *Ozotoceros bezoarticus*, and wild boar, *Sus scrofa* – Bianchi et al. 2013; collared peccary, *Pecari tajacu* – Bianchi et al.

2010). Although the consumption of larger prey may be the result of scavenging behavior, several authors have mentioned that ocelot, especially large adult males, can actively prey upon larger prey species (Sunquist and Sunquist 2002; Moreno et al. 2006). Therefore, the ocelot may also have some negative influence on activity of rural free-ranging dogs.

Occupancy patterns of the rural free-ranging dogs and ocelots

Contrary to what we hypothesized, we did not detect any influence of ocelots on patterns of occupancy of rural free-ranging dogs, or vice versa. Occupancy models were not robust enough to allow us to infer what might be constraining or promoting the spatial patterns of dogs or ocelots in the REBIO Serra do Japi. Indeed, given that the most supported model for free-ranging dog occupancy was the null model (i.e. low QAICc/AICc and high QAICc/AICc weight; Tables 2, 4; Suppl. material 2), it would seem that the covariates included had no or a negligible effect on occupancy patterns of dog and ocelots. Our small sample size could be contributing to the lack of discrimination. Therefore, future studies should reanalyze the spatial ecology of rural free-ranging dogs and ocelots within or close to protected areas using a wider data set. Such a strategy would allow for the confirmation (or not) of the detected lack of effect of the covariates tested here, but that were identified elsewhere as important drivers of free-ranging dog occupancy patterns (e.g. Torres and Prado 2010; Paschoal et al. 2016).

Conclusions

Although acknowledging that our data has some limitations due to the small sample size and the grouping of data from two different time periods, which should lead to a cautious interpretation of our results, our study still points out some ecological patterns that should be further investigated. Our data suggest that rural free-ranging dogs adapted their activity to avoid the main activity periods of ocelots, which also reduced the interference of the dogs with wild prey. Therefore, the management of protected areas subjected to incursions by rural free-ranging dogs should prioritize the protection and promotion of resident medium-sized to large felids, as they may inhibit dog activity in those areas and thereby act as a protective measure for threatened prey species.

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Supplementary material 1

Kernel densities for paired activity patterns of free-ranging dogs and ocelot (A) and free-ranging dogs and tapiti (B) in REBIO Serra do Japi, considering only the sample period of 2009/2010

Authors: William Douglas Carvalho, Luís Miguel Rosalino, Maíra Sant'Ana M. Godoy, Marília F. Giorgete, Cristina Harumi Adania, Carlos E. Lustosa Esbérard

Data type: occurrence

Explanation note: Individual records are shown as short vertical lines above the x-axis. The grey areas represent overlapping activity periods and the vertical dashed lines the approximate time of sunrise and sunset.

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Link: https://doi.org/10.3897/neobiota.45.30645.suppl1

Supplementary material 2

Rural free ranging dogs occupancy models for Serra do Japi Biological Reserve

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Data type: occurrence

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Supplementary material 3

Occupancy and detectability probabilities variation of the independent variable included in the best models

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Data type: statistical data

Explanation note: Variation of occupancy and detection probabilities with changes in distance to houses (km).Variation of occupancy and detection probabilities with changes in ocelot's occupancy probability.

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Supplementary material 4

Image of a rural free ranging dog registered in the Serra do Japi Biological Reserve

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Data type: occurrence

Explanation note: This was a small size individual (ca. 10–15kg), ranging alone.

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